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RESEARCH ARTICLE

Distribution of ground beetles of the genus *Bembidion* (Coleoptera, Carabidae) in the agricultural landscape in Northwestern Russia

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Abstract

We have observed seven species of predator beetles of the genus *Bembidion* in the agricultural landscape of the Leningrad Region (Northwestern Russia) between the years 2008 and 2018. These species reach their highest abundance in sun-exposed areas, especially mesophilic *B. quadrimaculatum* Linnaeus, 1761, *B. properans* (Stephens, 1828), *B. lampros* (Herbst, 1784), and *B. femoratum* Sturm, 1825. A few mesohygrophilic *B. guttula* (Fabricius, 1792) and *B. gilvipes* (Sturm, 1825) live primarily in areas of dense vegetation. Finally, the hygrophilic *B. bruxellense* (Wesmael, 1835) was only observed on the most humid soils. Assemblages of *Bembidion* ground beetles were separated in the fields, field boundaries, and adjacent habitats.

Keywords

Biodiversity, predator beetles, spatial distribution, agricultural landscape

Introduction

Bembidion Latreille, 1802 ground beetles, are an inherent part of agrobiocenoses in various regions. They are known to be predators that reduce the abundance of many dangerous pests (Shurovenkov, 1977; Sunderland, 2002; Madsen et al., 2004; et al.).

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Their distinctive feature is prey on phytophagous insects in the egg phase. In Canada, small *Bembidion quadrimaculatum* Linnaeus, 1761 were more likely to prey on the *Sitona lineatus* Linnaeus, 1758 eggs, than larger *Pterostichus melanarius* (Illiger, 1798) ground beetles (Vankosky et al., 2011). The significant number of researches was done regarding the abundance of ground beetles in agrocenoses (Shurovenkov, 1977; Honěk, 1997; Eyre, Luff, 2004; Guseva, Koval, 2015; Baranová et al., 2018; Putchkov, 2018; Vician et al., 2018; et al.). However, the distribution of these predators across agricultural landscapes, including different fields and adjacent habitats, is understudied, since it is desirable to have a temporally and spatially developed experimental crop rotation surrounded by natural biocenoses. Such special conditions were created at the Menkovo Research Station (MRS, Menkovo, Gatchina District, Leningrad Region) of the Agrophysical Research Institute (ARI, Saint Petersburg). Studying the spatial distribution of the *Bembidion* beetles in such conditions would help us understand under what conditions the number of these predatory insects grows in the agrocenoses.

Material and methods

This study was performed during 2008–2018 in MSR agricultural landscape (Fig. 1, 2). The data were collected using pitfall trapping (Guseva, 2018; Guseva, Koval, 2019) and soil sampling (Fig. 3). The soil sampling was conducted in May 2018 in the field of the experimental temporally and spatially developed crop rotation. In the first group, the fields were occupied with the overwintering timothy grass and rye; in the second, the fields were plowed after timothy grass and rye last autumn.

The research was carried out in the fields and the adjacent field boundaries and forest edges of the MRS (Fig. 4). In total, more than 1000 *Bembidion* individuals were collected. All arthropods captured in pitfall traps, including *Bembidion* beetles, were counted. The total activity density was measured (ind./100 trap-days).

We contrasted the twelve samples of beetles from different pitfall traps using the Bray-Curtis distance matrix from the pvclust package in the R software (R Core Team, 2020). The data were calculated using a matrix with biotopes listed in the rows, species listed in the columns, and the cells containing the numbers of beetles collected. Then, we compared the patterns of their clustering.

Results and discussion

Seven Bembidion species (*B. quadrimaculatum*, *B. properans* (Stephens, 1828), *B. lampros* (Herbst, 1784), *B. guttula* (Fabricius, 1792), *B. gilvipes* (Sturm, 1825), *B. femoratum* Sturm, 1825 and *B. bruxellense* (Wesmael, 1835) were observed in MRS agricultural landscape between 2008–2018.

Figure 1. The MRS agricultural landscape (spring wheat and adjacent habitats, May 2008).

Figure 2. The MRS agricultural landscape (timothy grass and post-harvest rye residues, May 2018).

Figure 3. Soil sampling on the rye (A) and timothy grass (B) fields, May 2018.

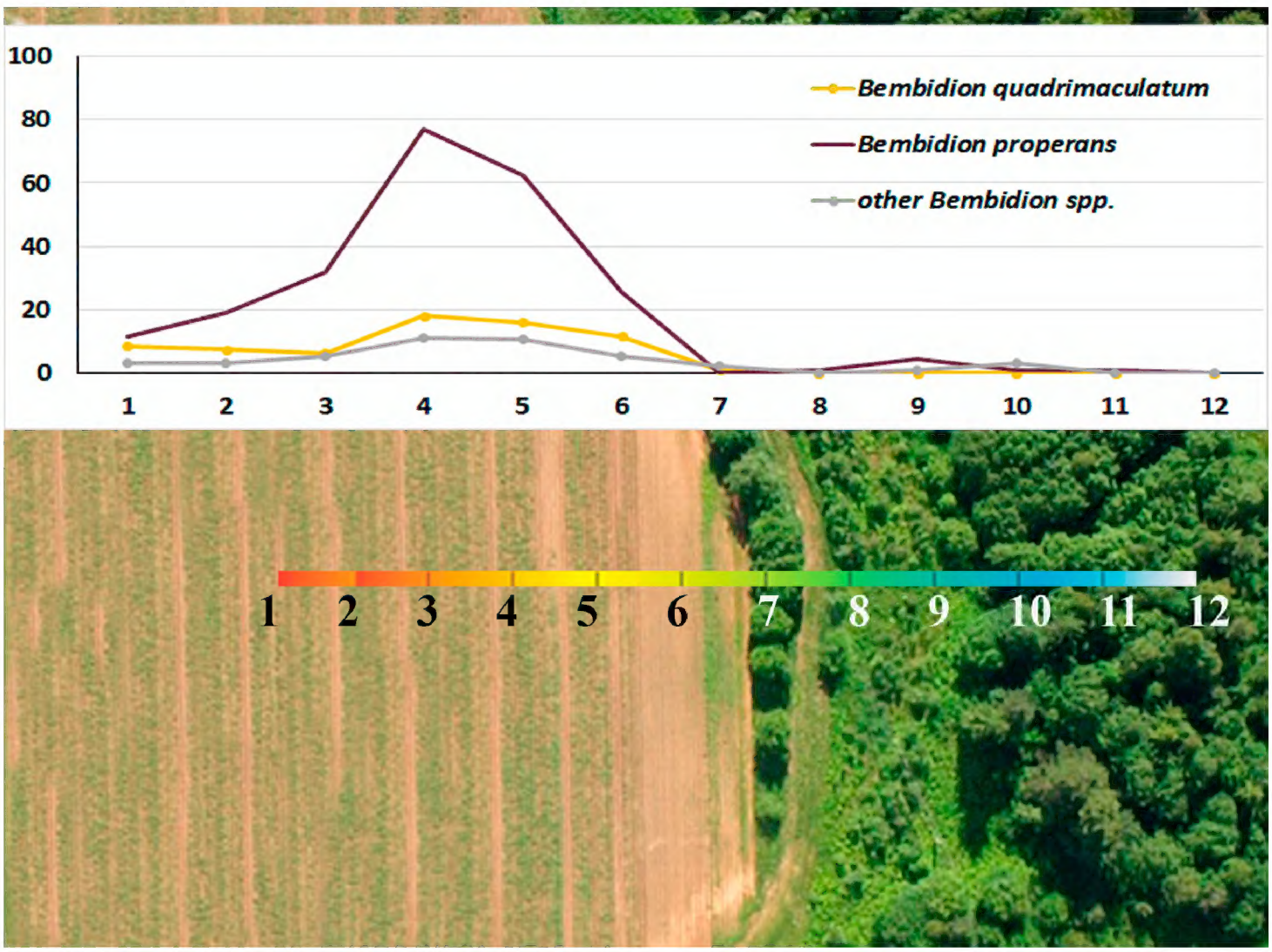

Figure 4. Activity abundance (ind./100 t.-d.) of ground beetles of the genus *Bembidion* in different parts of the MRS agricultural landscape. We used 12 traps, where traps 1–6 were installed in the spring wheat field, 7 – in the field boundaries, 8–10 – in adjacent semi-open habitats, 11–12 – on the forest edge.

Among them, *B. quadrimaculatum*, *B. properans*, and *B. lampros* were demonstrated to be the most abundant in the field. For instance, in the year 2008 in the spring wheat field, the activity abundance of *B. properans* was as high as 40.6 ind./100 trap-days, (11.9 and 6.7 for *B. quadrimaculatum* and *B. lampros* respectively), whereas only a few individuals were registered in the adjacent field boundaries and adjacent semi-open habitats (Fig. 4).

Throughout this study period, *B. guttula* were found only in adjacent semiopen habitats, and *B. gilvipes* – only in the field boundaries. Therefore, the *Bembidion* ground beetle complexes in the spring wheat field (trap 16) are different from those in the field boundary (trap 7) and adjacent semi-open habitats (traps 8–11) (Fig. 5).

We observed *B. guttula* and *B. gilvipes* in perennial grasses fields and in the fields plowed after three years of perennial grasses (Fig. 6). Nevertheless, their density was low compared to other specimens of their genus.

The results of the analysis of soil samples and pitfall trapping proved the mesophylic species of *B. properans* and *B. quadrimaculatum* (Fig. 6) to be the most abundant.

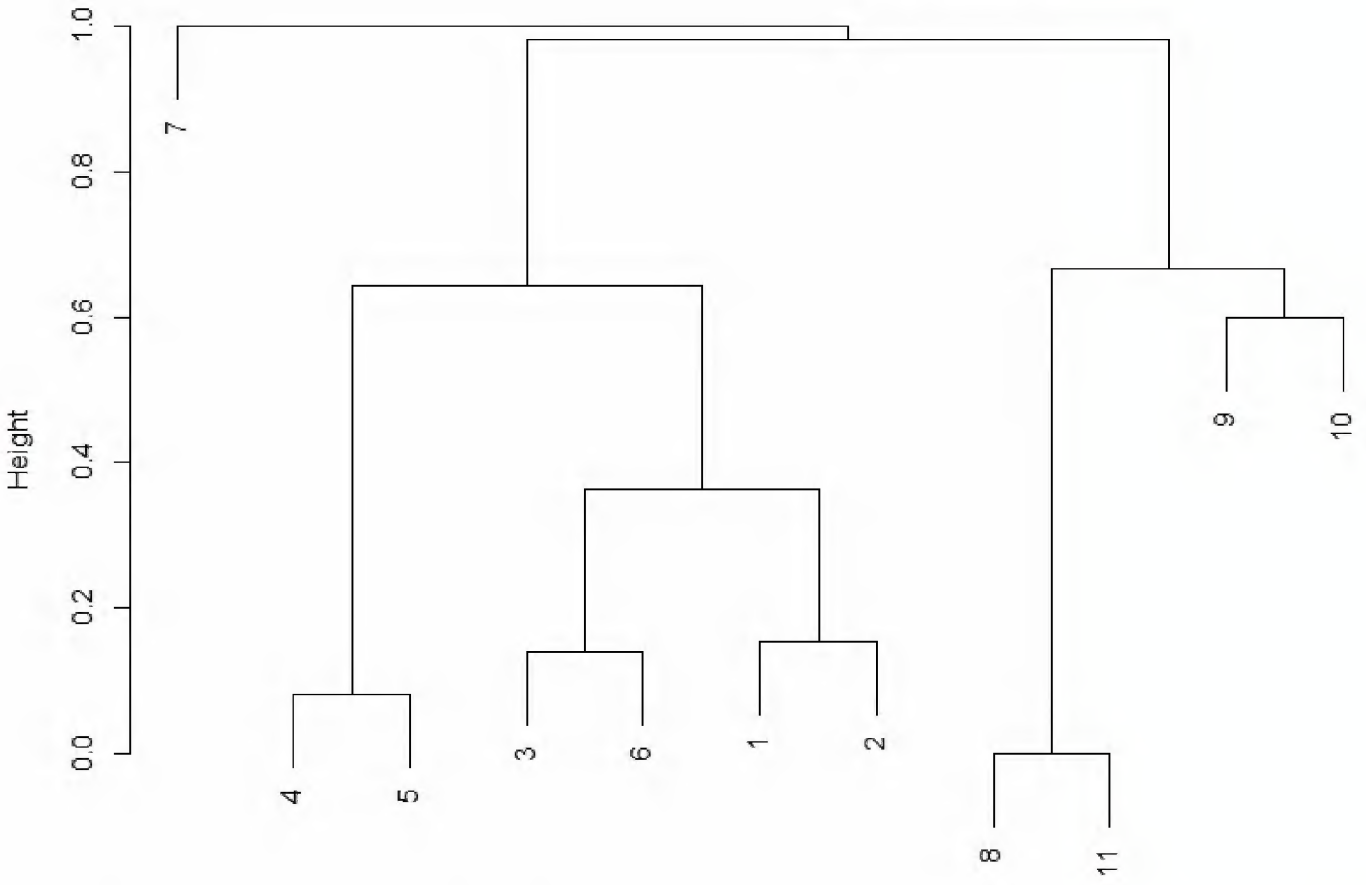

Figure 5. Dendrogram showing the results grouped by the Bray-Curtis method. 1–10 – number of traps: 1–6 – spring wheat, 7 – field boundaries, 8–11 – adjacent semi-open habitats.

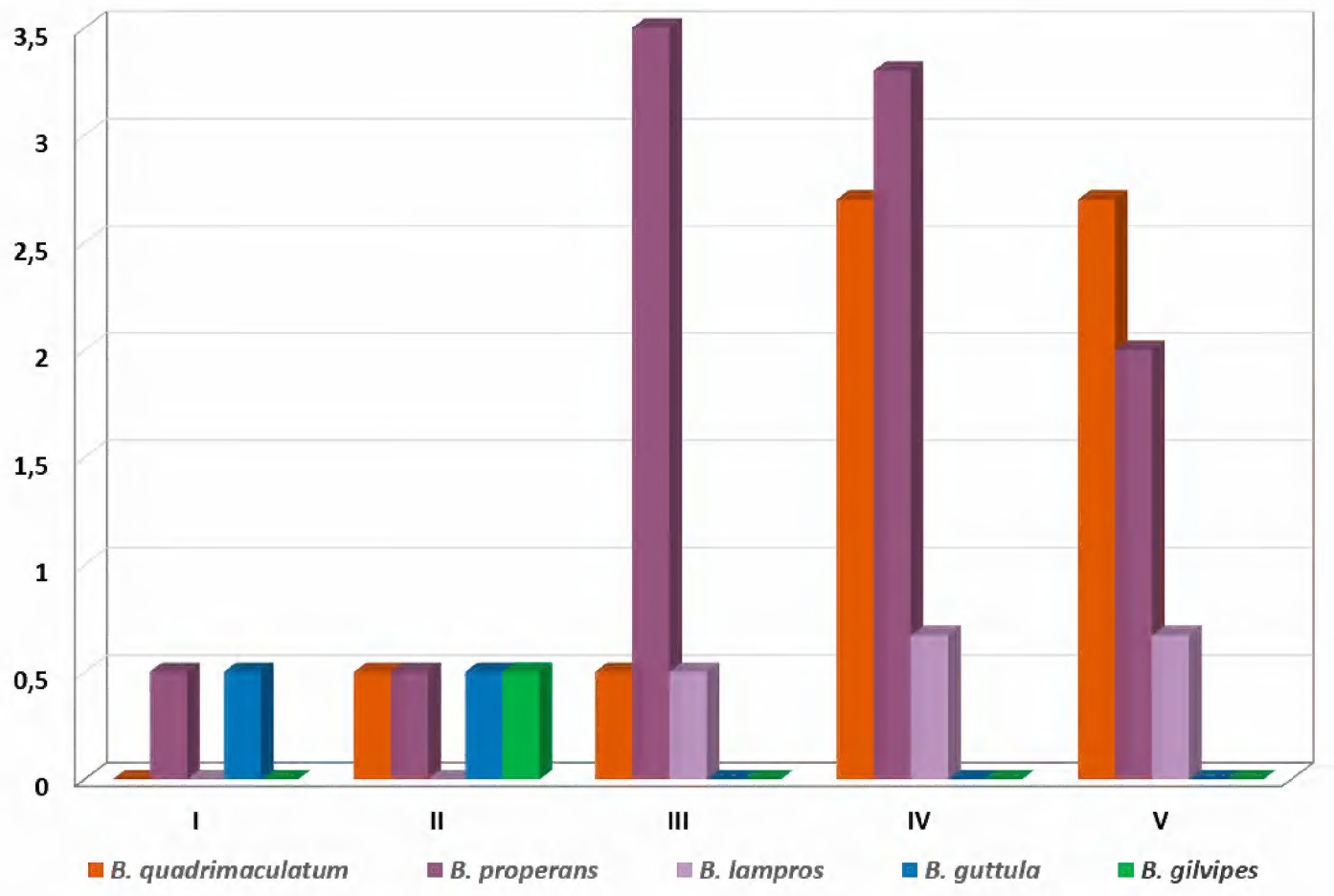

Figure 6. The density of the *Bembidion* genus ground beetles (individuals per square meter) in different fields of the crop rotation (according to the results of soil samples, May 2018). I – fields of perennial grasses; II – field after perennial grasses; III – field of winter rye; IV – field after winter rye; V – field after potatoes.

It is known that *B. quadrimaculatum* prefers sun-exposed areas with bare ground or sparse vegetation (Lindroth, 1985; Hance, 2002; Guseva, Koval, 2011). For instance, *B. quadrimaculatum* stays the most numerous species in MRS agricultural landscape in clean fallow fields on the bare ground throughout the entire season, while its density in the fields of annual plants decreases as these plants grow (Guseva, Koval, 2011). This pattern also occurs in other countries. In the Czech Republic, *B. quadrimaculatum* is known to be registered among the species that prefer bare ground (Honěk, 1997). *Bembidion quadrimaculatum* in northern England and southern Scotland was positively related to the tilled land (Eyre, Luff, 2004). In Poland, *B. quadrimaculatum* is 7.6 times more abundant in the field than in the field margins (Bennewicz, Barczak, 2020).

In the MRS agricultural landscape, *B. properans* is more abundant in low vegetation and moderate humidity and is very rare in more shadow habitats. The density rates of *B. lampros* go in hand with *B. properans*, albeit consistently scoring lower. On the contrary, in more southerly regions, *B. lampros* is known to have higher density rates than *B. properans*. For instance, in Central Slovakia, on agricultural plots with alfalfa, the numbers of trapped *Bembidion lampros* individuals are known to be 6.5 times larger than those of *Bembidion properans* (Vician et al., 2018).

The most numerous and active species of the *Bembidion* genus tend to choose the most sun-exposed areas with sparse vegetation for hunting, and this knowledge can be of high practical importance. For instance, in the north of Sweden, the intercrop of red clover had resulted in a decrease in the abundance of the *Bembidion* genus ground beetles in the cabbage fields (Björkman et al., 2010). At the same time, the density and feeding of these beetles were associated with the egg survival rates of the cabbage root fly (Guseva, Vol, 1996).

Bembidion genus ground beetles are an inherent component of agroecosystems in the row crop fields (e.g., cabbage and potatoes) with the bare soil in row spacing. Among them, *B. properans* and *B. quadrimaculatum* are the most common in Northwestern Russia. The role of these predator beetles can be multifaced. For instance, *B. quadrimaculatum* was registered in cabbage fields eating eggs of *Delia radicum* (Linnaeus, 1758) (Diptera, Anthomyiidae) (Guseva, Koval, 2013) and in potato fields eating eggs of *Leptinotarsa decemlineata* (Say, 1824) (Coleoptera, Chrysomelidae) (Koval, 2009).

Humidity is one of the most, if not the most critical factor for some of the species of the *Bembidion* genus. *B. bruxellense* is the most hygrophilous species of this genus in the MRS agricultural landscape. Only a few of its specimens occurred in cultivated lands of the MRS, and only in the year 2012, in the fields of overwintering wheat, in the relief depressions with more humid soil.

Mesohygrophilic species of *B. guttula* and *B. gilvipes* in the MRS agricultural landscape live mainly in areas of dense vegetation, more humid and shaded (in grasses, field boundaries, and forest edges). *Bembidion guttula* in the Czech and Slovak republics are also common in moist to wet habitats (Hůrka, 1996).

B. guttula in agroecosystems in Latvia also prefers habitat with denser vegetation and moisture microclimate (Gailis et al., 2017). In Fennoscandia, *B. guttula* tends to inhabit open lands with rich vegetation (Lindroth, 1985).

Only in certain years of study have we observed mesohygrophilic *B. femoratum* in the fields of MRS, and only in agrocenoses with the scarce vegetation or in open areas.

Conclusion

The predator ground beetles of the *Bembidion* genus tend to have a highly uneven distribution in the agricultural landscapes of Northwestern Russia. Assemblages of ground beetles of the *Bembidion* genus in the field are separated from those in adjacent habitats. Therefore, adjacent habitats (field boundaries with dense vegetation and shrubs and forest edges) cannot add to the increase in the density of mass *Bembidion* species in fields. The only source from which the number of these entomophages can grow (for example, after using insecticides that are highly toxic for these ground beetles) – or, more precisely, be supplemented – is other fields with sun-exposed areas of sparse vegetation or bare soil. The dense vegetation areas are unfavorable for the specimens of this genus, except for only very few mesohygrophilic *B. guttula* and *B. gilvipes*. Mesophilic *B. properans* and *B. quadrimaculatum* are the most numerous species of the *Bembidion* genus in the agrocenoses of Northwestern Russia. These species prefer sun-exposed areas with sparse vegetation.

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